The Los Alamos Reservoir: A Gauge for Increased Erosion after the Cerro Grande Fire, Los Alamos, New Mexico

Alexis Lavine [1], Danny Katzman [1], Steven L. Reneau [1], Gregory A. Kuyumjian [2], Jamie N. Gardner [1], Daniel Malmon [1,3]

[1] Los Alamos National Laboratory, [2] U.S. Forest Service, [3] U.C. Santa Barbara

Abstract

The Cerro Grande fire of May 2000 burned approximately 17,400 ha in the eastern Jemez Mountains in the vicinity of Los Alamos, New Mexico. Changes in surface characteristics caused by the fire, including the development of hydrophobic soils and the loss of vegetation and litter layers, resulted in major increases in runoff and erosion relative to pre-fire conditions. This study documents sedimentation in the Los Alamos reservoir, located in upper Los Alamos Canyon, providing a unique datum for estimating pre- and post-fire erosion rates in a montane watershed. The reservoir was built in 1943 for water storage, and had a maximum holding capacity of ~46,000 m^3. The drainage basin upstream from the reservoir has an area of 16.5 km^2, ranges in elevation from 2320 to 3180 m, and largely supported a mixed conifer forest prior to the fire. Thirty percent of the basin experienced moderate to high severity burn during the Cerro Grande fire, including some of the steepest parts of the basin; 33% experienced low severity burn and 37% was unburned. Draining of the reservoir to mitigate the potential for flooding down-canyon allowed for detailed surveying of the top of pre- and post-fire sediments. A total station survey in June 2000, following a single post-fire flood, showed a holding capacity of ~34,800 m^3. The post-fire deposits in the reservoir were less than 0.3 m thick, and comprised ~1,600 m^3 of sediment deposited during 1 event. This yields an estimate of ~8600 m^3 of sediment accumulation in 57 years, or an average of ~150 m^3/yr prior to the fire, equivalent to an average basin-wide denudation rate of ~ 0.0095 mm/yr. This low rate is consistent with the well-vegetated nature of the basin prior to the fire, and the absence of evidence for extensive surface runoff and erosion. When the total station survey was repeated in June 2001, a large delta front consisting of gravels and sands had formed a subaerial platform at the head of the reservoir. The post-fire deposits also included finer sand and silt mixed with ash in medial and distal subaqueous portions of the reservoir. These deposits comprised ~20,200 m^3 of sediment that had accumulated in one year, equivalent to an average denudation rate of ~1.2 mm/yr, or about 135 times the average pre-fire rate. Assuming that all of the sediment was derived from the high and moderate severity burn areas yields an average denudation rate of ~4 mm/yr for those areas or about 450 times the pre-fire rate. Approximately 65% of post-fire sediments in the reservoir were deposited in the summer of 2000, and the large delta was formed in the spring of 2001. Field observations suggest that much of the sediment was derived from scour of alluvial fills along the channels, although the relative contribution from hillslopes and channels has not been quantified.

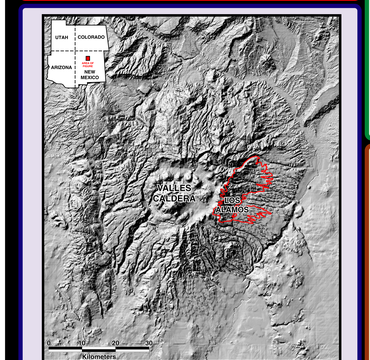


Figure 1. Map showing the location of the study area in north-central New Mexico and shaded relief map of the Jemez Mountains showing the Valles caldera, the town of Los Alamos, and the area burned in the Cerro Grande fire (outlined in red).

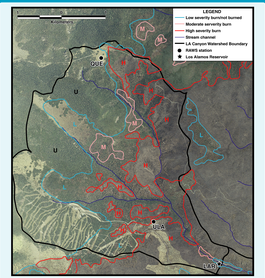
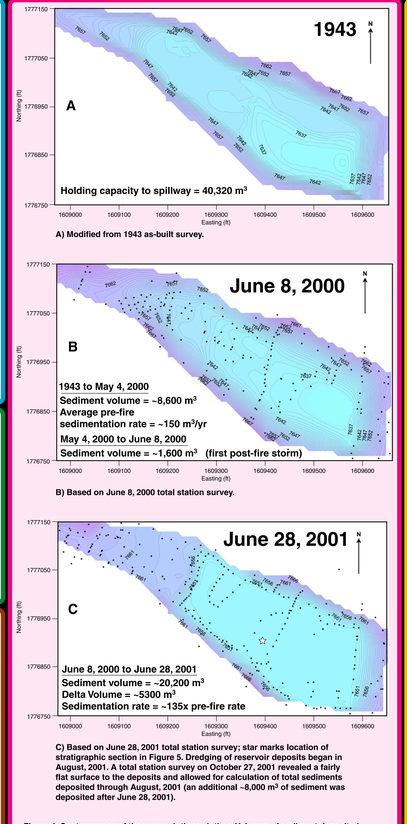


Figure 2a. Aerial photograph showing the Los Alamos Canyon drainage basin (thick black outline) above the Los Alamos reservoir (LAR) and burn severity from the Cerro Grande fire (blue=low severity (L) or not burned (U), pink=moderate severity (M), red=high severity burn (Hi)). The drainage basin above the reservoir encompasses 16.5 km^2, 30% of which experienced moderate to high severity burn. The basin ranges in elevation from 2320 to 3180 m, and largely supported a ponderosa pine/mixed conifer forest prior to the fire. Rain gauges (RAWS (Remote Automated Weather Station) stations), QUE=Quemazon and ULA=Upper Los Alamos, in the upper watershed are shown by black dots.

Figure 2b. Oblique aerial photograph looking west of Los Alamos Canyon and the reservoir, taken shortly after the fire.

Figure 3. Photograph of total station surveying in the reservoir (June 28, 2001). Three total station surveys of the sediments deposited in the reservoir were performed in the first 1.5 years after the fire.



A) Modified from 1943 as-built survey.

B) Based on June 8, 2000 total station survey.

C) Based on June 28, 2001 total station survey; star marks location of stratigraphic section in Figure 5. Dredging of reservoir deposits began in August, 2001. A total station survey on October 27, 2001 revealed a fairly flat surface to the deposits and allowed for calculation of total sediments deposited through August, 2001 (an additional ~8,000 m^3 of sediment was deposited after June 28, 2001).

Figure 4. Contour maps of the reservoir through time. Volumes of sediment deposited during distinct time periods are calculated from surfaces interpolated from total station survey data using kriging. Coordinates are in the State Plane Coordinate System (in feet), New Mexico Central Zone, NAD83.

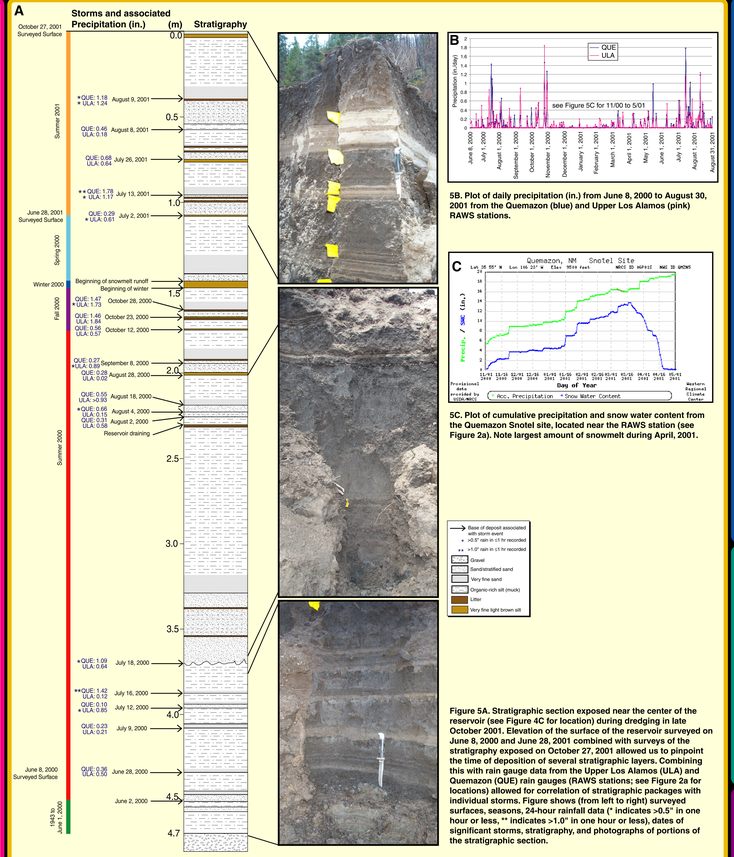


Figure 5A. Stratigraphic section exposed near the center of the reservoir (see Figure 4C for location) during dredging in late October 2001. Elevation of the surface of the reservoir surveyed on June 8, 2000 and June 28, 2001 combined with surveys of the stratigraphy exposed on October 27, 2001 allowed us to pinpoint the time of deposition of several stratigraphic layers. Combining this with rain gauge data from the Upper Los Alamos (ULA) and Quemazon (QUE) rain gauges (RAWS stations; see Figure 2a for locations) allowed for correlation of stratigraphic packages with individual storms. Figure shows (from left to right) surveyed surfaces, seasons, 24-hour rainfall data (* indicates >0.5" in one hour or less, ** indicates >1.0" in one hour or less), dates of significant storms, stratigraphy, and photographs of portions of the stratigraphic section.

5B. Plot of daily precipitation (in.) from June 8, 2000 to August 30, 2001 from the Quemazon (blue) and Upper Los Alamos (pink) RAWS stations.

5C. Plot of cumulative precipitation and snow water content from the Quemazon Snotel site, located near the RAWS station (see Figure 2a). Note largest amount of snowmelt during April, 2001.

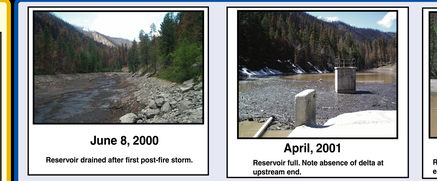


Figure 6. Photographs showing evolution of the reservoir from June 2000 to October 2001.

Conclusions

The Los Alamos Reservoir served as an excellent catchment for sediments eroded from the 16.5 km^2 upstream drainage basin, 30% of which experienced moderate to high severity burn during the Cerro Grande fire in May 2000.

Based on total station surveys done in 2000 and 2001 and the as-built survey of the reservoir from 1943, the total volume of sediments deposited in the reservoir in the 57 years prior to the fire is ~8,600 m^3, yielding an average sedimentation rate of ~150 m^3/year. The total volume of sediment deposited between June 2000 and August 2001 is ~29,800 m^3. From June, 2000 to June, 2001 approximately 20,200 m^3 of sediment was deposited, yielding an average yearly sedimentation rate 135 times the pre-fire rate for the watershed. Assuming that all of the sediment was derived from the high and moderate severity burn areas yields an average denudation rate about 450 times the pre-fire rate in the first year and half after the fire. Because of channel erosion downstream of high severity burn areas, the actual increase in denudation rates in high severity burn areas may be less. The relative amount of sediment derived from hillslope erosion vs. channel erosion has not been quantified, although both sources may be important. A more accurate estimate of denudation rates requires subtracting the amount of reworked ash deposited in the reservoir.

Total station surveying of the surface of the deposits through time allowed for calculation of the volume of sediment deposited during specific time intervals. Dredging of the reservoir in October, 2001 exposed over 4.5 meters of post-fire sediments near the center of the reservoir. Comparing survey data from October, 2001 to survey data from the summers of 2000 and 2001 allowed for correlation of the elevation of sediment packages with the dates of the surveys, and correlation of individual sediment packages with storms recorded at 2 rain gages (RAWS Stations) upstream.

On-going studies: Samples were collected for analysis of organic matter content and bulk density to better quantify the amount of ash vs. inorganic sediment deposited in the reservoir, and to more accurately calculate erosion rates in the watershed. Two additional stratigraphic columns were measured toward the upstream side of the reservoir, and allow for comparison of sediment packages with location in the reservoir.

Acknowledgments

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